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Internet of Things and Healthcare Technologies: A Valuable Synergy from Design to Implementation

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Abstract

Internet of Things (IoT) promises to be a reliable technology for the future. Healthcare is one of the fields which are rapidly developing new solutions. The synergy between IoT and healthcare promises to be very beneficial for human healthcare and evolved into a new field of research and development: the Internet of Medical Things (IoMT). This paper presents a review on various enabling IoMT technologies based on the latest publications and technology available in the marketplace. This article also analyzes the various software platforms available in the field of IoMT and the current challenges faced by the industry.

Keywords

Internet of Things

Internet of Medical Things,

State of the art,

IoT, IoMT

Healthcare

1. Introduction

During the last years, the synergy between the fields of Internet of Things (IoT) and Healthcare - the Internet of Medical Things (IoMT) is becoming increasingly more apparent. Many researchers from disparate fields are working on smart Healthcare devices able to connect to the internet. IoT in combination with Cloud Computing are increasingly more getting the valuable support for the next generation eHealth [1] Services. By 2020, the Healthcare IoT market [2] is expected to grow to $330 billion, according to global market analyst Grand View Research (see figure 1). Many governments are aware of the potential of Smart

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Healthcare Devices and ready to invest and promote the use of eHealthcare Services. The cost and quality of existing Healthcare systems can be improved with the help of IoT Based Healthcare Systems. This paper gives an overview of the current State of the Art of the IoMT and it provides the background information to better understand the challenges and open issues in this field.

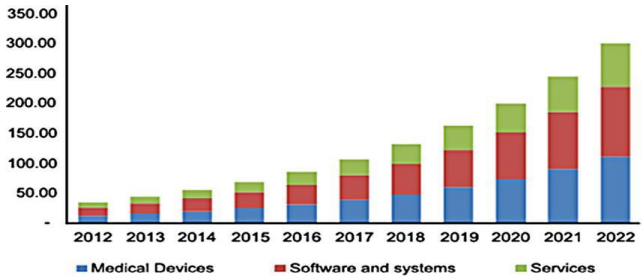

Figure 1. IoT in Healthcare market growth [2]

The architecture of an eHealthcare System [3] is divided into three components: 1. Device Layer, 2. Internet Connected Gateways Layer, and 3. Cloud Computing Layer (see figure 2). Medical data like heart rate and pulse rate can be directly assessed by the user, such as a medical doctor. The eHealthcare system can then take Intelligent Actions and propose the proper medical treatment.

A system that can support the operations in the office or company such as system to manage orders, is called a Backend System. Backend Systems work on the Cloud (Computing) Layer and consists of two parts: 1) Cloud based back-end infrastructure, which includes data storage and intelligent decision-making, and 2) User interface "dashboard" platform, which displays the user controls and data visualizations. Due to advanced intelligence systems and the Machine Learning technique, an IoMT health system is automatically set up as a duplex communication system which can predict patient health and take intelligent decisions if necessary, such as starting a treatment according to the diagnosis of the detected health problem.

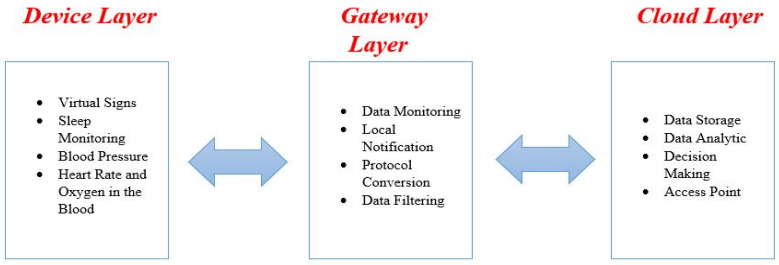

Figure 2. Architecture Block Diagram of IoMT

This next sections of this article are organized as follows: section 2 covers the IoMT based research studies, section 3 presents the IoMT enabling Technologies, and section 4 covers platform support for IoMT, section 5 presents the IoMT industrial market, and finally, section 6 presents the conclusions and future research areas are discussed.

2. Internet of Medical Things Studies

Many researchers are working on the IoMT, to make IoMT enabled medical devices smart and cost effective. Bui and Zorzi [4] proposed a framework for the healthcare applications. They developed an IoT stack protocol framework and measured the advantages of the protocol. Hassanalieragh, Page, Soyata, Sharma, Aktas, Mateos, Kantarci and Andreescu [5] reviewed Cloud based Health Monitoring system opportunities and challenges for future healthcare. They highlight the following challenges: sensing, and visualization for the design of the system, as the essential ways to improve healthcare and reducing cost. Rodrigues, Segundo, Junqueira, Sabino, Prince, Muhtadi and Albuquerque [3] present IoT based Healthcare techniques to analyze problems like Heart Rate, Oxygen saturation in the blood, and ECG and discusses enabling technologies for IoMT and the latest products available for IoMT service providers, researchers and

technology developers. Alansari, Soomro, Belgaum and Shamshirband [6] have reviewed usage of IoT in the health sector. They identified two criteria for achieving sustainable development for the IoT: 1) Economic prosperity and 2) Quality of life. Mahmud, Koch and Buyya [7] introduced a solution for healthcare called Fog-Based IoT Healthcare Solution. This HealthCare solution is analyzed with the use of iFog Simulator and in relation to Power Consumption and reduction of latency. The results of these simulations is helpful for the reduction of the price, network delay and power consumption. Sharma, Chen and Sheth [8] conducted a study called k-health – a platform is developed for monitoring diseases such as Diabetes, and Blood Pressure Problems.They built data mining algorithms for the preservation of privacy, which is relevant to the healthcare solution. These algorithms help to improve the privacy and cost. Maia, Batista, Cavalcante, Baffa, Delicato, Pires and Zomaya [9] developed an EcoHealth platform for sharing Real Time Data between doctor and patient. The main aim of this platform is to improve Health Monitoring and Medical Checkups for patients.

The studies discussed in this section illustrate how the synergy between the IoT and Healthcare is beneficial for improvements to the medical field and the challenges and open issues. We will examine the various enabling technologies and software platforms available to date, for IoMT research and development in further section.

3. Various IoMT Enabling Technologies

The IoMT system architecture, consisting of three layers (Device Layer, Internet connected gateway and Cloud Layer), allows a connection between a patient and their medical personnel, such as a medical doctor. It provides e-health facilities for continuous monitoring of heart rate, body temperature, blood pressure, blood sugar, electrocardiography, electromyography, skin problems and brain hemorrhage.

In the IoMT Architecture, data is collected from the human body via medical sensors. The output of the sensors is in electrical form and these signals are processed via Microprocessors or Microcontrollers and then this output is directly forwarded to the User Terminal. The User Terminal is connected to a layer which enables the end users' client or near user device to carry an amount of stored data, called Fog Layer with the help of Communication Protocols such as Wi-Fi, Bluetooth, NFC, nrf24l01, ZigBee, etc. This Fog Layer is connected with the cloud layer. The Cloud Layer is used for Data Storage and Data Processing. The Cloud Layer also makes a backup for the patient data or history like "The number of times the patient visits the clinic" or "Reasons for hospital visit".stem this will be the significant territory of concern. IOT worldview will have pass on user's request for the data validation & protocols such that its request can be assess against the policies so that they can give or deny access. There is a prerequisite for new protocols & definition because the accompanying requirements can't be expressed from this present scenario [3].

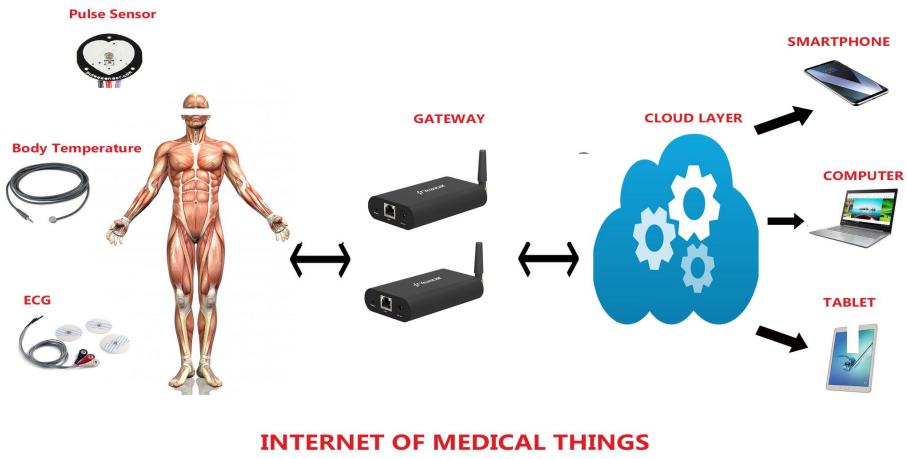

Figure 3. Architecture of IoMT

The IoMT are categorized into many enabling technologies but for the purpose of our review, we are focused on those technologies which are mostly used by the Universities and Industries for research of: 1) Remote Patient Monitoring, 2) Telehealth, 3) Wearable Devices for the IoMT Solution, 4) Software Platform for the Smartphones. We discuss these technologies one by one below, in sections 3.1 - 3.4 respectively.

3.1. Remote Patient Monitoring

Remote Patient Monitoring Systems are IoMT systems via which patients can be monitored at any place at any point in time. Remote Health Monitoring systems are beneficial for care homes, hospitals, healthcare centers and clinics. They can easily communicate and monitor health problems, in real time. It can potentially help reduce hospital waiting time and treatment time, decrease clinical treatment costs and improve the quality of care for the patients. Remote Health Monitoring Systems can be operated via Android or iOS applications and these applications are then directly connected via the Cloud Layer to the user terminal on smartphones, tablets or smart watches. Medical sensors will send data like oxygen saturation in the blood, heart rate, or pulse rate directly to the user's smart device in the emergency situation (see figure 4).

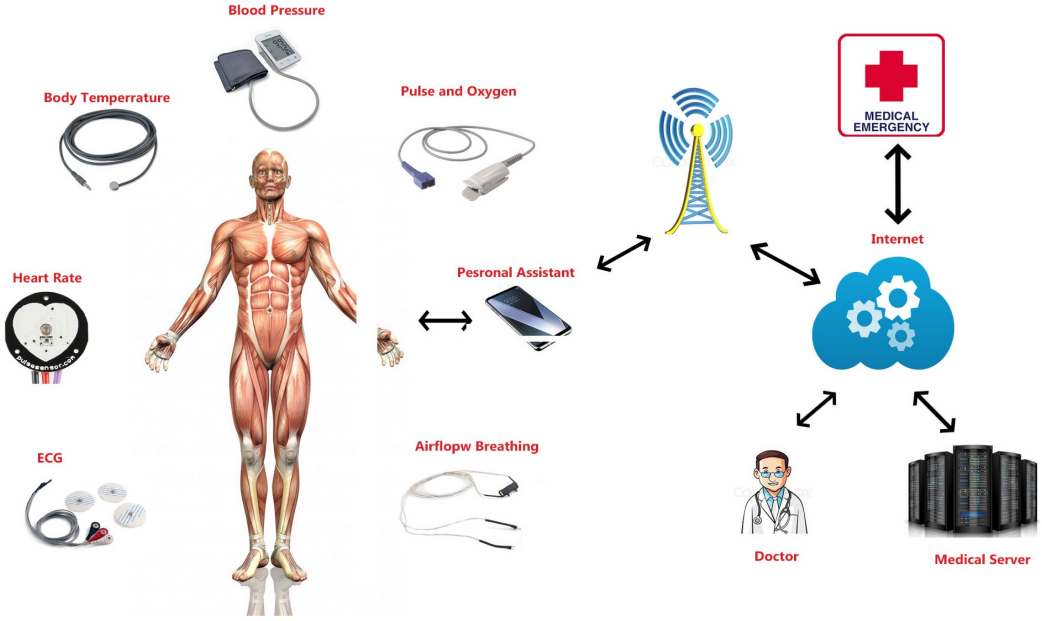

Figure 4.Illustration Architecture of Remote Patient Monitoring System

The Remote Monitoring Healthcare System is divided into three tiers: 1) Wearable Sensors, 2) Cloud Layer, 3) User Terminals (such as tablets, smartphones, web portal, smart watches). The first tier in this system consisting of Wearable Sensors, is used to collect data like Pulse and Heart Rate, which is transmitted directly to the second tier. There the data is processed and stored in the Cloud Layer. The Cloud Layer receives data with the help of various communication modules such as Wi-Fi, Bluetooth or a 2.4 GHz Wireless. In the third tier of the system, hospital or clinical faculties access the data on smartphones or web portal. The Remote Monitoring Healthcare System uses multiple sensors to acquire health data and provides this real time processed information to the medical doctor as well as patients' smartwatch. Based on these results, the medical doctor can provide guidance to patients, for instance: "What to do to recover from the diagnosed disease" or "Which diet is better". The User Terminal consists of four modules of operations: 1) Storage data for the patient or about the patient, 2) Management system, 3) Patients view their stored data number of times, 4) Provide treatment advice according to requirements. Every Remote Monitoring Healthcare System has two parameters to make it a Real Time Health Monitoring System: a. Energy efficiency b. No delay between data transmission and reception.

3.2. Telehealth

Telehealth is a bidirectional audio-video communication between Healthcare Service provider and a patient in their place of residence (see figure 5). Telehealthcare facilities provide a virtual physical presence of the medical doctor to the Patient's home for the medical treatment and monitoring of the patient and their vital signs. Due to the two-way communication, diseases can be detected by the medical doctors through monitoring their vital signs and providing medical assessments via the Telehealthcare system

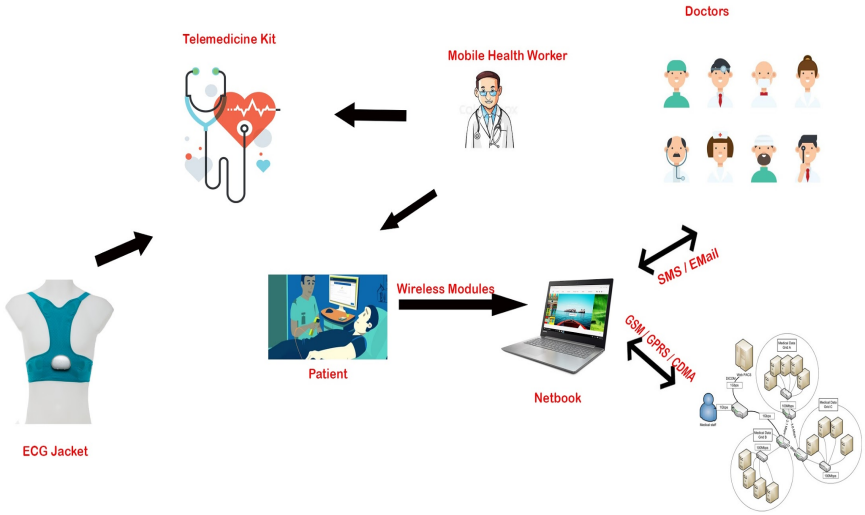

Figure 5. Illustration Architecture of Telemedicine

Telemedicine applications consist of three modes: 1) Save and Forward 2) Tele-meeting, 3) Video-meeting. Save and forward, stores a patient's medical history and diagnosis report in a file with the help of Electronic Medical Record (EMR) [13]. The EMR software sends the report to the medical doctor for advice. Telemedicine can help reduce or bypass the typical problems of waiting-times and travel time, when taking an appointment with a medical consultant. However, this technique is not suitable in case of health problems that require immediate treatment. Tele-meeting is a consultation between different parties' discussions regarding the patient's health through audio via Internet. It is also suitable as a medium for a discussion between patient and doctor about the medical treatment. Video-meetings have so far been found to be the most beneficial and appropriate method for a long-distance medical discussion [21]. It uses both audio and video, and requires high bandwidth and the cost of the equipment can be high if they using Radio Frequency (RF) components for audio and video.

Telehealth is categorized into different domains: 1) Synchronous and Asynchronous Transmission and Reception of Data, 2) Remotely Monitored Medical Data

3.3. Wearable Devices for IoMT Solutions

Wearable Devices are smart devices that can be worn by the user or patient and collect medical data like Heart Rate, Pulse Rate, Body Temperature and transmit this data directly to the Cloud Service Provider Via Gateway. In a Wearable Device, the sensor and processor should have small in size and power efficient. Wearable devices - such as Smart Glasses, Smart Watch, Smart Shirt, Wireless key tracker, Smart Shoes, Smart Shirts and Pants, Smart Belt and Smart Bracelets - can be beneficial for elderly people, for the monitoring of vital signs during physicals activities.

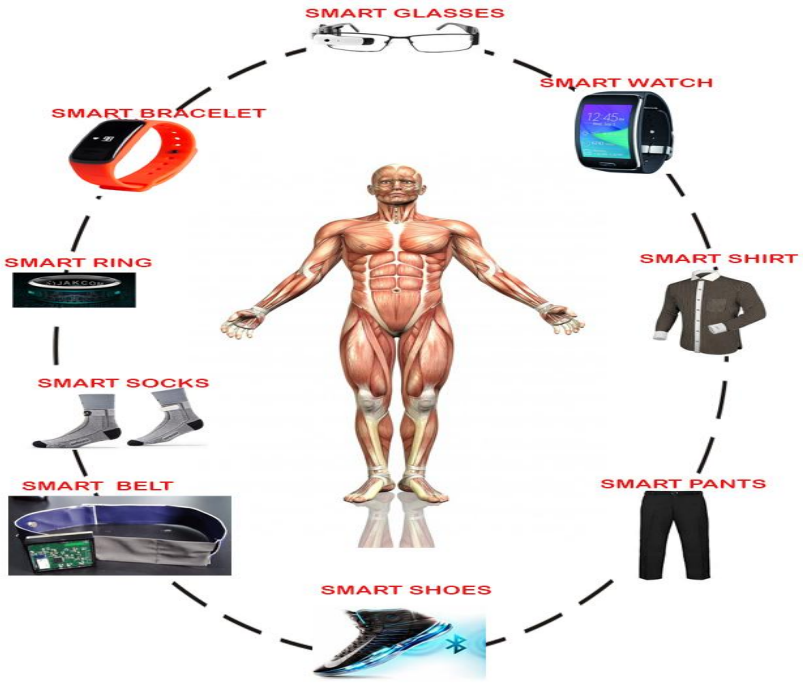

Figure 6. Illustration Architecture of Wearable Technology

Wearable devices are rapidly becoming more popular and the main motivation behind using wearable technology is that the user can monitor their own physical response to exercise more effectively and they can adapt their exercise routine accordingly, during their daily workout. This wearable technology is directly connected to the smartphone or tablet, for processing of the daily collected activity information. The following two problem areas for Wearable devices have been identified that are different compared to other kind of Wireless Networks [15]:

1. Power Consumption: preferred batteries are small in size and operate on a very low voltage and current. Bluetooth and Wi-Fi are not suitable because they have up to ten times more power consumption.
2. Interaction between two or more signals: Signal interaction between wearable devices and wireless networks is creating a challenge. Cybersecurity experts have warned that wireless data from wearable devices is a gold-mine for computer hackers. This problem is eliminated only if an up-to-date security infrastructure is in place.

3.4. Software Platform for the Smartphones

With the advances in technology development, the adoption of self-monitoring devices also increases. Self-monitoring devices [16] provide a health analyses and suggest how to treat heart diseases, diabetes, blood pressure, cancer or other health related problems. Many healthcare companies provide and integrate these medical technologies into a daily medical routine. For instance, healthcare companies have developed unique “apps”[20], for patients who are unable to go to the clinic for their routine checkups.

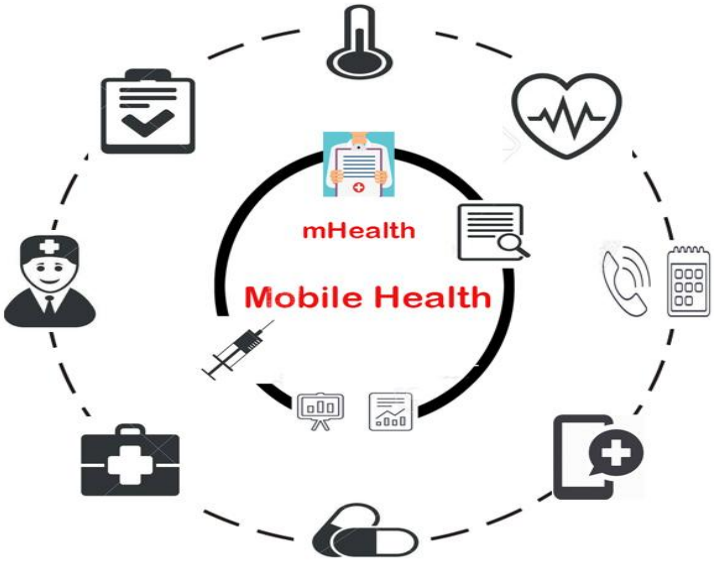

Figure 7. Illustration Architecture of Smart Devices

These apps are directly connected to the clinician's or doctor's user terminal. These app will be useful in the following ways.

3. Digital Health Records : Digital health records are being integrated by many hospitals and private clinics, via their servers, for access to patient records via smartphones apps. With the help of this integration users can access their data anytime from anywhere. For instance, a patient can see available appointments of the doctor and this can potentially save time and resources.
4. Management of Diseases: Disease management [18] apps are the most convenient and beneficial way to improve the efficiency of Healthcare. With the use of this kind of app, the career can stay directly involved with the patient and monitor progress and treatment of the diseases in real time.
5. Socially Active :Patients are connected to other patients via social media and can discuss and compare their experiences with the treatments they receive. Hospitals always encourage the patients to use social media and compare their experiences with others. Patients can significantly benefit from using mHealth apps. These mHealth apps can help patients review their health statistics and records, in real-time, provide guidance for the effective management of their illness or diet and help connect them with other patients via social media type chat-groups related to their illness and health goals.

We analysed that Remote Monitoring system for healthcare system plays a important role in the Medical Field. It helps to reduce the waiting and treatment time and provide a better treatment with low cost. Telehealth provides the audio-video facility between patient and doctor. It reduces the travel time or cost and send the patient medical records directly to the doctor for the advice but this technique is not beneficial in the emergency situation. Usage of the Wearable devices are increasing day by day and help to collect medical data like heart rate, pulse rate , body temperature and send to the Users terminal but still consumes more power and not energy efficient devices. mHealth app is used for health analysis and suggest how to treat with the diseases. It helps to store the digitally health records but this mHealth APPs are only working in the online mode if it gets offline no storage of data.

4. Platform support for IoMT

Currently every big company is trying to improve their services to increase their presence on the medical market. Specifically, every big provider of Cloud Services is enhancing their services to

accommodate IoMT Devices. They are providing and developing intelligent services for the businesses, including hospitals. Most of the available platforms consider the same IoMT architecture and follows the end to end solutions. The main components of the IoMT architecture are :

1. IoMT Sensors: Medical sensors helps to fetch the data toward Cloud Section
2. Gateway: Gateway is used to collect and filter data. It provides Internet Connectivity to all data centers.
3. Storage: Data is analyzed with the help of gateway and send to the storage section which help us to maintain, configuration, and control of data.
4. User Terminal Applications: At the user terminal, there is a software compatibility app like Android or iOS, to display the analyzed data in the proper manner.

The worlds' main IoMT vendors and companies provide services for healthcare applications as follows:

4.1. Amazon Web Services (AWS) IoT

AWS IoT provides dual communication between IoMT sensors and the Amazon Web Services Cloud. Medical Companies are developing framework for healthcare with the use of the AWS Cloud Service.

Figure 8. Components of the AWS IoT Platform

AWS has developed AWS Green glass software, which allows industries to securely process messaging and synchronizing for the connected devices. According to the AWS Services [17], AWS clouds can be connected with millions of devices and supports billions of messages from end to end points with high security and reliability.

4.2. Qualcomm Life Platform for Healthcare

Qualcomm Life is another platform used for the Healthcare applications. It provides end to end solutions for the Healthcare Clinics, patients and doctors. Qualcomm Life is based on a Cloud Platform that allows or connects with a huge number of medical devices and helps to collect, analyse and store the medical data. This data is transferred with the help of short range communication modules like Bluetooth, Wi-Fi.

Figure 9. Qualcomm Life Ecosystem

The main components in the Qualcomm 2net are:

1. 2net Hub: Device in which installed at User Home to communicate with the medical devices and collect data with the help of radio. It is a Plug & Play device.
2. 2net Mobile: Mobile software app which is installed at the user's home to collect the transmitting data via gateway.
3. 2net Platform: Cloud-based system that enables point to point exchange of the medical information transmission, and connection with the medical devices.

4.3. Microsoft Azure IoT Suite

Azure IoT is a Microsoft IoT solution in Cloud Computing, capable of sending and receiving millions of messages every second. Azure IoT manages communication of device to cloud and cloud to device. It can communicate with millions of medical devices simultaneously and supports HTTP and MQTT (Message Queuing Telemetry Transport) for sending data from device to cloud and cloud to device.

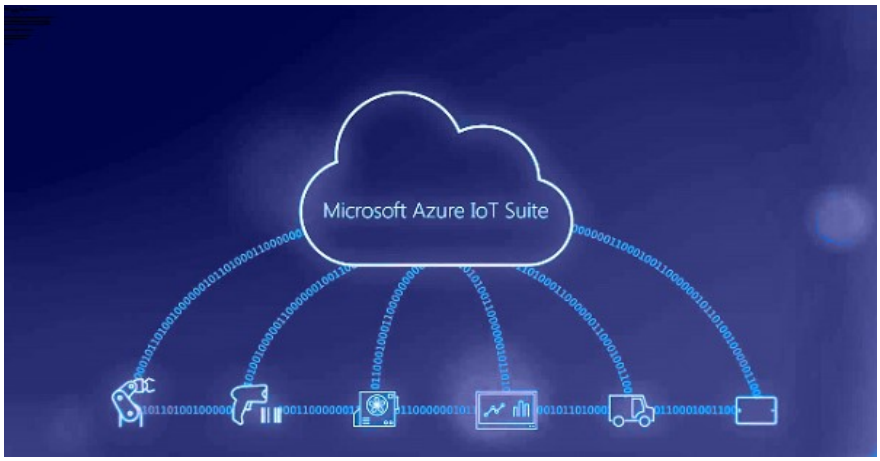

Figure 10: Azure IoT Suite

One of the main challenges in the development of IoT platforms, is the Cloud Connectivity to the medical devices. Azure IoT overcomes this challenge as follows:

1. Device Twin: A JSON document that can help to store the metadata for configuration of the device. It helps to synchronize the sharing of data between the app and the backend database.
2. Secure Connectivity: Durability is a very important factor in the IoT service. The Azure IoT Suite provides durability between the cloud and device through feedback or acknowledgement with every message. It also provides secured communication using the Transport Layer Security and X.509 protocol.

3. Secure Processing: With the help of Azure Active Directory, the Azure IoT Suite provides an authentication to access and manage Cloud Data. It enables this level of security via the Azure Cosmo Database.

4.4. Intel IoT Connecting Medical Devices to the Cloud

The Intel IoT has developed the end to end model architecture and its environment is combined with the third party to provide solutions for the medical devices to securely connect with the cloud. Intel has developed a platform which can support connectivity for millions of medical devices with Intel Cloud and the architecture is deployed with few key point:

1. It helps to autonomously setup the device connections from device to cloud and cloud to device.
2. It facilitates the simplification of protocols and format of data.
3. It secures the IoMT platform at both hardware level as well as software level.
4. It provides real time monitoring and real time analysing from device to cloud and cloud to device.

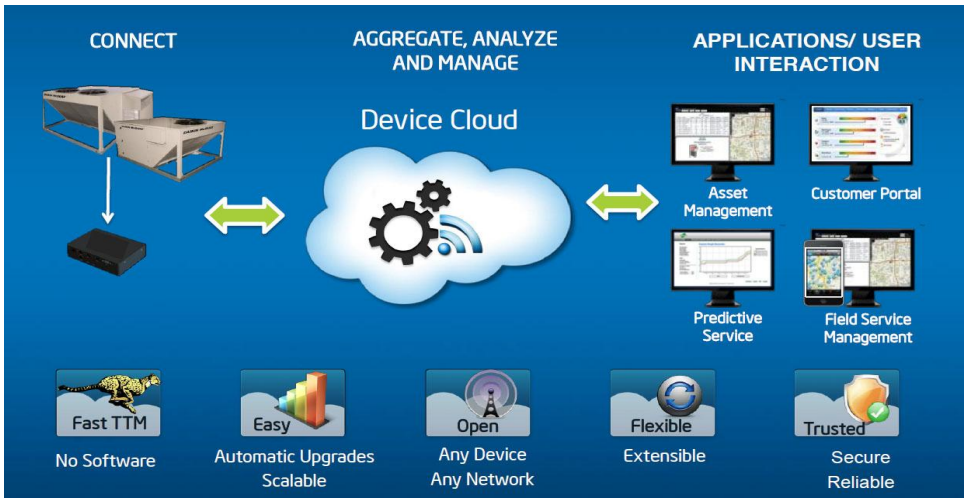

Figure 11: Intel IoT

Intel IoT provides a solution for addressing some challenges, such as high cost due to using of outdated equipment's, and the fact that technology used for remote monitoring may not be properly compatible with the needs and abilities of an aging population.

We analysed that many big companies are trying and launching the IoT services for the HealthCare. AWS has launched the software called Green glass which help to process and synchronize messages very securely. It provides very high security and reliability. Qualcomm life allows to connect the millions of medical devices and it helps to store and analyse the data of connected devices. Microsoft Azure IoT suite is another platform for the IoMT. It helps to support the millions sending and receiving messages in every second and provides the highly secure connectivity and secure processing with the help of Azure Cosmo Database. Intel has also launched one IoT platform for the medical devices which is autonomously setup the bidirectional connection between cloud and devices. It provides high security and real-time analysing between the cloud and devices. It also helps to replace the outdated medical equipment's and reduce the cost.

5. IoMT Industrial Market

With the increasing adoption of IoT technology, the research rapidly goes to a new direction. IoT is continuously growing to the Medical Sector and enhance the opportunities for the industry to reduce the cost.

The IoMT industry is rapidly growing and it is generating many discussions and explorations of novel application areas. Start-ups, university research labs and (multinational) companies are developing new

products and moving onto the market to implement the IoMT devices. The IoMT market will reach $136 billion by 2021 according to the Allied Market Report [19].

At present, the IoMT industry is mainly focused on the healthcare technologies like Wearables and Smart Technology. Mobile devices are already equipped with Near Field Communication (NFC) and Radio Frequency Identification (RFID), so they can easily communicate with medical devices through the cloud. Table 1. Presents a IoT companies supports HealthCare. High speed Internet and sponsorship from the government, also help grow the IoMT industry.

Recently, Ericson presents a report [22][23] called “Role of 5G in the Healthcare Sector”. In this report, Ericson says that in remote monitoring system, there is a requirement of updations of data at very high frequency rate existing technologies cannot fulfil the requirement while connecting with millions of devices.

Table 1: IoT companies and products support IoMT

Company	Product	Product Type	Brief Description
Naya	Naya Smart Breast Pump	Device	Naya Breast pump is a hydraulic suction pump used for baby feeding. It embed with app to display the session data for pumping and milk volume.
Orbita	Orbita Voice	App	Orbita Voice is a app which creates a virtual assistant and connect with clinical person to capture feedback from the smart devices like google home.
Trulnject	Trulnject	Kit -Model and Software Application	It is IoT connected injection training system which includes model and software system for the practice on injectable medication
Carré Technologies	Hexoskin - Wearable Body Metrics	Device - Smart wearable shirts	Hexoskin is a IoT enabled shirts to measure the ECG , Heart rate , breathing rate and sleep cycle.
Breathometer	mint	Device	Mint is a device which enabled with the IoT to monitor the oral health.It analyze the oral bacteria and send the immediate feedback to the mint app.
Keriton	Keriton Kare Nurse	APP	This app provides the IoT based platform to reduce the NICU nurses workload and help to care the children's.It can save more than 10000 NICU nurses data.
Meru Health	Meru Health Ascent	APP	Meru Health Ascent is a mobile program that gives the Precision treatment for the burn out.

6. Conclusion and Future Scope

The IoMT is playing an important role in enhancing the healthcare industry. One of the fastest growing industries in the medical field is the IoMT, which is why we did this review of IoMT enabling technologies. Furthermore, we analyzed the recent publications about the IoMT and presented the enabling technologies that are used by the healthcare industry and presented the top IoMT platforms developed by

industry for healthcare technologies. These solutions are essential for society because to demonstrate further insights into the latest IoMT developments, we also provided a broad overview of the latest trends, technologies, industrial platforms, challenges and open issues like Wearable Technologies. Basically wearable technologies

Wearable technologies face the following challenges:

1. Wireless Modules like bluetooth consumes more power,
2. Pattern recognition and machine learning require more storage.
3. Government support needed for Healthcare governance, user and manufacturer rights.

This overview does not provide in-depth information about IoMT security, but recognizes it as an essential element of success for the IoMT and further research is needed to address these issues. However, it has provided and overview of the security challenges, topologies and architectures. The Latest technologies like electronics patches, Big data , virtualization are very important in the Medical Sector and it should be considered in the future research.

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